Integrated process of Ecosystem Services evaluation and urban planning. The experience of LIFE SAM4CP project towards sustainable and smart communities

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Integrated process of Ecosystem Services evaluation and urban planning. The experience of LIFE SAM4CP project towards sustainable and smart communities.

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Abstract

Evaluation of Ecosystem Services (ES) and related mapping tools and techniques can be used in urban planning and design to define sustainable land use strategies aimed to achieve resilience in urban planning.

The analysis of ES improves the ability of politicians, administrators, planners and stakeholders to define strategies of regeneration, ecologically and energy efficient oriented. Furthermore, it allows to reflect about the sustainability of urbanization and related environmental issues, bringing attention to social and economic aspects, too. The soil, as measurable value common good, is a source of energy, requires a strong reduction of its consumption and a good use of it.

The paper experienced the recent research innovations made by DIST for LIFE program SAM4CP, which integrates the process of planning and decision making with analysis and assessments of ES in order to support Municipalities to define policies and monitoring procedures oriented to limit the consumption of high quality soil. The process of evaluation and planning can also be adopted for urban resilient projects aimed at define successful methods for improving energy efficiency in communities and urban areas. The paper aims to present partial results of the project. A strong integration of evaluation and planning actions, providing multicriteria analysis techniques and adopting software (like InVEST) able to map the outcomes of the evaluation process and the inputs for the planning process will be discussed.

An indicator based approach is presented as the innovative tool to achieve land use efficiency, and resilience as the main paradigm to steer Co-planning Conference.

1 Introduction

In the Italian context few research activities related to land use planning are designated to introduce operative innovation over the traditional framework of systems and powers. The gap between the theoretical advancement of research on land use sustainability and its "real" application is affecting the practices. Nowadays, the environmental approach on land use planning is mainly referred to the bureaucratic procedure of plans approval rather than the construction of a knowledge system embedded with Strategic Environmental Assessment procedure. By the way great amount of skills are required to improve the technical framework for land use sustainability considering its practical application.

The LIFE project SAM4CP[1] made by DIST-Politecnico di Torino[2] aims to connect the scientific knowledge on Ecosystem Services (ES) allowing a better territorial decision mechanism. The project leads to include the ecological assessment of soil within its economic value also accounting alternative land-use scenario.

ES refers the conditions, process, and components of the natural environment that provide both tangible and intangible benefits for sustaining and fulfilling human life [1]; its measurement is codified by the publication of Costanza et al. *The value of the world's ES and natural capital* (1997) which present an economic valuation of the goods and services that human population derive, directly or indirectly, from ecosystem functions. Recently, has emerged an important discussion concerning the definition of a common international classification of ES (CICES) [2].

Associated with the land use changes and the observation of the land take by new urbanization, the valuation of the ES help to enforce the decision making mechanism. The methodological evaluation of land use impacts, when defined by scientific standard procedures embedded on local plans construction, became a basic tool to define trade-offs between alternative uses and scenarios and thus being communicative with stakeholder (public and private ones).

Among others, specific phases of the project are aimed to define a scientific methodology to assess ES for local planning. In particular, the core of the project is to find benchmarks for planning evaluation, here intended as the thresholds for a Soil Quality Indicator (SQI) that holds the most important information for an efficient use. Efficiency, is due to the capacity of the soil to "fit with the use" without a permanent alteration that drastically decrease other potential uses. Related to this, is the possibility to achieve resilience over planning activities.

The definition of a SQI request a previous construction of ES assessment with a high technological degree of innovation over planning activities, which is mainly based on new ES mapping activity.

Three main phases of the LIFE project are designed to define such SQI and concerned to mapping and assessing ES:

- the identification of models for biophysics and economic evaluation of ES. With the legacy of the previous LIFE projects, some approaches were compared and evaluated by a preliminary research. This phase was aimed on pointing out a set of tools for ES economic and ecologic evaluation;
- the collection of input data for running the models to ES evaluation. This phase was crucial for launching and testing the software for ES evaluation. Input were collected primarily for the main functions defined by the project (carbon sequestration, water purification, contrast to soil erosion, maintenance of biodiversity, provision of habitat for pollinators; wood/fiber production; food production);
- the application of the model (production of preliminary output) and the evaluation of comparative results. In this phase two crucial sub-phases were requested:
    1. to find out the benchmark to test different result of research for specific ES evaluation;
    2. to evaluate and compare between them scenarios output.

[1] Title of the Project: Soil Administration Model for Community Profit. Project leader: Città Metropolitana di Torino responsible for the actions 3, 4 as well as a management and administrative management of the project; Partner (1): Politecnico di Torino – Interuniversity Department of Regional and Urban Studies and Planning; Partner (2):ISPRA – Istituto Superiore per la Protezione e la Ricerca Ambientale; Partner (3):CREA – Consiglio per la Ricerca in Agricoltura e l'Analisi dell'Economia Agraria.

[2] The DIST research group is composed by: Prof Carlo Alberto Barbieri (Scientific Responsable), Prof. Giuseppe Cinà, Prof. Angioletta Voghera; with an operative team of research fellows composed by Dr. Arch. Carolina Giaimo, Dr. Dafne Regis and Dr. Stefano Salata.

The testing of models through evaluation of input/output data is aimed to be prepared at launching the models using a case of study (which is the Municipality of Bruino in the metropolitan area of Tourin - Italy) and testing the full operability of ES assessment for the construction of a local land use plan.

Once ES are mapped and fully assessed by biophysical/economic sides the project aims to capture the “flows of value” that a land use variation produce to the initial stock. It is the “quality”, rather than the “quantity” of used soil to be analyzed because such information is crucial for a better integration of sustainable/resilient strategy of land use management in terms of energy systems: only a deep knowledge on ES flows supports strategies of mitigation and compensation for land transformation[3].

2 Resilience

The concepts of “sustainability”, “development” and “growth” required a re-contextualization of the socio-economic changes and dynamics taking place in the current global scenario.

In particular, the debate around climate changes – and related issues - prompt a change of the paradigm in the way planning cities is undertaken, with an emerging attention to resilience and adaptability of land use planning. The concept of resilience - initially used in the mechanical and metallurgical domains – became established in the sciences concerned with complex adaptive systems: biology, ecology, sociology, psychology. Since a few decades, it has also been used in town planning as the capability of a city to adapt to any external intervention, bothman-made or caused by climate change, in order to restore its own balance. The concept of resilience focuses attention on the dynamics of persistence and adaptation taking place within the observed system[4]. Furthermore, resilience is already the affirmation of a proactive approach that can be glimpsed or pursued[5].

Planning for increase urban resilience urges a significant renewal of planning activities with a view to new methods of acquiring knowledge and cope with existing issues, as well as adequately support the evaluation of planned land use scenarios.

A key element in planning for urban resilience and fostering the adaptive capacity of a city, is the development of environmental infrastructures (blue, green and slow) to build a new city around the "commons" (water, soil, green areas, energy , waste, mobility), their spaces and their management. This approach would trigger positive loops for the recycling of scarce resources and foster proactive policies, overcoming approaches of land use limitations[6]. For instance, actions for climate change mitigation require radical improvements in the functioning of a city, i.e. the use of both land and buildings through water and energy networks. Particularly, a strategy to mitigate climate change requires significant reductions in greenhouse gas emissions, but the development of a planning activity focused on greenhouse gas emission reduction require a good knowledge of soil properties that interact with the composition of gases on atmosphere.

The methodology adopted by SAM4CP entails several possible solutions to design urban settlements with the aim of minimising carbon emissions and improving the quality of public open spaces. The proposed analysis improves the knowledge about the ecological quality of the soil using ES assessment as the value of an ecological indicator for a context based area. The deeper the knowledge of ES value and spatial distribution, the greater the possibility that these features are properly considered as part of planning and urban design.

Moreover, SAM4CP addresses the issue of how the success of this “new paradigm” in plans, policies and projects, implies to the forms of organization and decision-making of the territorial government, using multilevel governance to engage all the various stakeholders involved in the dynamics of land use planning development. Through the tool of Co-planning Conference, SAM4CP is experimenting urban planning actions geared towards differentiation and synergy of institutional roles among various issues at different scales (regional, metropolitan and local levels).

3 Ecosystem Services Analysis

From systematic studies on surface and covers, to the complete assessment of urban transformation effects in all soil-related system, a huge amount of research deal with the question “what happened on topsoil, and under it, when a process of urbanization occurs" [7]. Despite this, few analyses are focused on environmental effect of land use change to ES provided by natural soils [8], especially the ones which requires integration across different disciplines [8].

Anyway, great deal of research is dedicated to estimate the single's environmental effect of land take process, especially using a specific ES as a proxy [9][10][11][12].

But even if ES approach clearly demonstrate that effect of land use change affect more than a single ecosystem [13][1], still persist a lack of technical assessment to introduce multidimensional indicators that hold different aspects of soil transformation (e.g. productive, natural, protective). Composite indicators on ES are far away from being rooted in scientific literature, but the demand for profound soil knowledge is high [14]. Reasons of such failure is that the creation of a SQI request a major interaction of scientists from other disciplines to achieve a broad holistic role in society; up to now the poor feedback between land use and soil related studies is limiting advancements[15].

3.1 The broad evaluation of Ecosystem Services

One of the most common approach of ES evaluation is the one that follow: *the total ecosystem services of each land use category can be obtained through multiplying the area of each land category by the value coefficient: ESV = ∑ (Ai • VCi) – where ESV is the estimated ecosystem service value (Euro•a-1), Ai is the area (ha) and VCiis the value coefficient (Euro•ha-1•a-1) for land use category "i"*[8].

The above mentioned definition, introduces the possibility to have an economic evaluation of ES. Even oversimplified [16][17]such possibility gives to public administration and planners the estimation of a stock and a variation value for environmental management through land use planning.
First exploration on ES values for specific land use/cover categories are reported on study "impact of urbanization on natural ecosystem service values: a comparative study"[18]. An example of output is given by Table 1 which present actual[3] economic values in euro for five major land use classes.

Table 1 ES value coefficient for each land use category

€ for hectares actualized					
services types	forest	grassland	agriculture	wetlands and water	barren
gas regulation	371,3	85,1	52,7	95,6	
climate regulation	286,1	95,6	94,0	932,4	
water regulation	338,9	85,1	63,1	1.904,5	3,2
soil formation and retention	413,4	206,6	154,8	90,7	2,4
waste treatment	138,6	138,6	173,4	1.929,7	0,8
biodiversity	345,3	115,1	75,3	264,2	35,6
food production	10,5	31,5	106,1	21,0	0,8
raw material	275,6	5,6	10,5	4,0	
recreation and cultural	135,3	4,0	0,8	523,6	0,8
total	2.314,9	767,2	730,7	5.765,9	43,7

Such approach was so long criticized by whom intended to state that it is not possible to fix pre-defined environmental values for land use classes, both because environmental goods are economically "intangible", and because it is impossible to commonly define a "price" without a site-specific situation.

And the critics was true, for the above mentioned reasons, but forgot to consider that the "fixed price" for land use categories is not defined to outline "which is the value of a specific ES" rather than to be used for comparative studies, to track the trend of growth or decrease associated to a land use variation. Indeed, when a land use change occur, the alteration to specific ES can be differentiated: the transformation of an agricultural field into an urban areas should decrease the "food production" capacity, but increase "biodiversity" because it alters surface adding huge green urban areas.

[3]Values in dollars per hectares were transformed in euro per hectares, with a coefficient of actualization of price of 0,7% here intended as the difference between inflation on 2005 and 2012. http://epp.eurostat.ec.europa.eu/inflation_dashboard/

The only way to holds all the complex system of information regarding land use variation is the association of a complete ES assessment to Land Use Change (LUC) scenario.

LUC allows to quantify the loss of ES as effect of change in cover or land uses[18]. Nowadays the creation of indicators for specific ES request a high account in research, especially for local planning [19][20]. But it is not the simple “quantification” of ES enough appropriate to support effective practices of land use planning: *the critical ways in which ecosystems support and enable human well-being are rarely captured in cost-benefit analysis for policy formulation and land use decision*-making [21].
It is important to remark that rather than absolute value, economic computation is useful to understand which is the present and future variation *between values* [22][23]. Such information gives better feedback to planners and politicians to steer local policies of land use transformation. Moreover, it is not the evaluation of a single’s ES function to be helpful for a trade-off analysis, but a complete ES assessment.
When an overall computation of different ES values has been monitored, and not a single function, results appear consistent: … *results showed that, although a conventional, market-dominated approach to decision making chooses options to maximize agricultural values, these policies will reduce overall values (including those from other ES) from the landscape in many parts of the country; notably in upland areas (where agricultural intensification results in substantial net emissions of GHG) and around major cities (where losses of greenbelt land lower recreation values). In comparison, an approach that considers all of those ES for which robust economic values can be estimated yields net benefits in almost all areas, with the largest gains in areas of high population… Our analyses suggest that a targeted approach to land-use planning that recognizes both market goods and nonmarket ES would increase the net value of land to society by 20% on average, with considerably higher increases arising in certain locations*[22].

The statement imply that, especially the definition of local planning policies, require the construction of a “complex” and “integrated” knowledge framework which overwhelm the traditional approach of alternative land use scenarios: it is not an evaluation between productive and urban uses enough to understand at all if an efficient and resilient use is planned or not. This is why a SQI is necessary.

SQI is important because refers to “quality” rather than the “quantity” of soil affected by anthropic processes. The soil quality is the capacity of a soil to function within ecosystem and land use boundaries, to sustain biological productivity, maintain environmental quality, and promote plant and animal health. It contributes to the investigation of several key ecosystem concerns: the productivity and sustainability of many ecosystems, the conservation of soil and water resources, the accumulation of persistent toxic substances, and the contribution of different land uses and covers to the global carbon cycle [24].Thus SQI is a fundamental key to achieve a better sustainable and resilient urban planning.

3.2 The case of study: methodology

The Municipality of Bruino is a small town (8.576 inhabitants) located south-west sector of the Città Metropolitana di Torino (north-west of Italy), it is a typical second ring Municiaplity, characterized by a rural landscape (52% of land is covered by agricultural uses, the 22% is covered by natural zones, and only the 24% is covered by the built up system, by which only 7% is covered to productive, commercial and public services areas) and a local productive/commercial economy. Urbanization had a strong development in the second part of the last century related to new residential areas and industrial districts.

In order to reduce the urban sprawl, a new Local Plan has been approved in July 2015, assuming the concept that “free soil” has an ES with a high value for environment and life quality in urban settlements and defining goals: limitation of soil consumption and construction of a local ecological network. Moreover, Municipality of Bruino is taking part as a key case study in LIFE activities, as a contribution to improve strategies already adopted and to enhance more the Local Land Use Plan.

The construction of ES values in the case of study has been reached using the software InVEST-Integrated Valuation of Ecosystem Services and Tradeoffs. The research presented considers the last release available (in 2015) of the InVEST model (version 3.1.0).

The software was used to estimate seven main ES: biodiversity, carbon sequestration, water purification, water yield, contrast to soil erosion, provision of habitat for pollinators; food production.

As introduced, the Municipality of Bruino (among other Municipalities) has been selected as a key case study in LIFE activities according to the letter of interest. The LIFE activity has to produce a variance of the Local Land Use Plan. This is why every model has been constructed to have a great deal of accuracy and precision for planning purposes: the challenge was not to use InVEST as a general tool for ES accountability, but to construct alternative scenarios of efficient land use planning for Co-planning phase.

The phase 1 of the project has been dedicated to run the software InVEST for each ES selected. In particular, actions were dedicated to:

- the construction dataset (using standard and ancillary data);
- the research of sources for input software values;
- the interpretation of output models.

Output of biophysical models were distributed on five per five meters cell, than associated economic values were founded.

Biophysical evaluation produces output per pixel expressed by (i) indexes or (ii) absolute quantities. The seven ES mapped by project were estimated using such units:

- index from 0 to 1 for Habitat Quality and Crop Pollinator;
- tons/pixel for Carbon Sequestration and Sediment Retention; mm/pixel for Water Yield; kg/pixel for Nutrient Retention;
- values form 0 to 8 for Land Capability Classification (Crop Production).

Subsequently, considering the previous LIFE+MGN (Making Good Natura)[4] project, the biophysical maps where used to associate economic values. Indeed, one of SAM4CP output is the estimation of economic values of soils on the base of their biophysical maps. With respect to this, a basic consideration have to be outlined: all estimated economic values are “potential” rather than “definitive” because they derived from market price of substitution/artificial production of a similar service which is normally provided by soil.

Table 2 Methodology for evaluation, adopted in the project LIFE SAM4CP

Ecosystem Function	Biophysical Value	Economic Value
Habitat Quality	The overall quality of the ecosystem (biodiversity) [index 0-1]	Cost of the “reproduction” of specific land uses that provides ES [20€/sq. m.]
Carbon Sequestration	Tons of sequestered carbon by soil [t/px]	Price for each ton of carbon stored [120€/mc]
Water Yeld	Liters of water removed by processes of evapotranspiration [mm/px]	Cost for removing water by artificial techniques as a construction of a lamination hydro-basin [12,6€/mc]
Nutrient Retention	Nitrates released into the water [kg/px]	Cost for the construction of green buffer zones useful to detention of nitrates [64€/kg]
Sediment Retention	Potential erosion avoided by soil [t/px]	Cost of rehabilitation of soil fertility, useful to the protection from erosion [22,8€/t]
Crop Pollinator	Gradient of optimal allocation for hives [index 0-1]	Average price of hive [44€/hive]
Crop Production	Productivity capacity [index 1-8]	Prices of specific crops [€/sq. m.]

[4]Project “Making Public Good Provision the Core Business of Nature 2000” (LIFE+11 ENV/IT/000168) coordinated by University Consortium (CURSA). For more information: http://www.cursa.it/ecms/uk/research/making_good_natura

While for ES with absolute values it is possible to define a price per unit, mistake arise when the economic value is associated to indexes. Even though with declared limitations, a “derived” value was still applied. An example is given by economic evaluation of biodiversity index. Such index was estimated from the price of “reproduction” of land uses that provides biodiversity in urban areas. Than the price of “substitution” (how does it cost to plant an urban forest?) was distributed using a linear function to all the land use categories. Therefore, all seven main ES were evaluated

Table 3 An example of ES assessment: Carbon sequestration

Land Use/Land Cover	Carbon Sequestration							
	t0		t1		Var (abs)		Var (%)	
	biophisic	economic	biophisic	economic	biophisic	economic	biophisic	economic
Continuous urban fabric (dense)	17,86	2.143,35	17,89	2.146,76	0,03	3,41	0,16%	0,16%
Continuous urban farbic (non dense)	366,20	43.943,55	762,49	91.498,28	396,29	47.554,73	108,22%	108,22%
Discontinuous urban fabric	7.727,02	927.242,68	7.634,46	916.134,86	-92,57	-11.107,82	-1,20%	-1,20%
Discontinuous urban fabric (sparse)	1.244,37	149.324,61	1.194,95	143.394,29	-49,42	-5.930,31	-3,97%	-3,97%
Industrial or commercial units (dense)	194,06	23.287,09	232,67	27.920,27	38,61	4.633,19	19,90%	19,90%
Industrial or commercial units (non dense)	64,44	7.732,93	71,90	8.627,87	7,46	894,94	11,57%	11,57%
Road and rail networks and associated land	2.486,12	298.334,91	2.433,22	291.986,99	-52,90	-6.347,92	-2,13%	-2,13%
Dumpsites (mine)	8,97	1.076,67	8,97	1.076,94	0,00	0,26	0,02%	0,02%
Dumpsites (deposits)	45,14	5.416,22	35,06	4.207,57	-10,07	-1.208,65	-22,32%	-22,32%
Construction sites	129,63	15.555,84	129,66	15.558,74	0,02	2,90	0,02%	0,02%
Unbuilded artificial soils	75,37	9.044,59	14,00	1.680,51	-61,37	-7.364,07	-81,42%	-81,42%
Artificial, non agricultural vegetated areas	157,03	18.843,36	47,63	5.715,78	-109,40	-13.127,58	-69,67%	-69,67%
Green areas	125,92	15.110,58	799,95	95.993,55	674,02	80.882,97	535,27%	535,27%
Urban parks	762,59	91.511,11	2.665,82	319.898,78	1.903,23	228.387,66	249,57%	249,57%
Uncoltivated urban areas	4.272,37	512.683,85	1.664,32	199.718,32	-2.608,05	- 312.965,53	-61,04%	-61,04%
Cemeteries	3,42	409,87	3,43	411,69	0,02	1,82	0,44%	0,44%
Sport and leisure facilities	289,72	34.765,95	289,98	34.797,88	0,27	31,93	0,09%	0,09%
Agricultural areas	9.261,19	1.111.343,00	8.458,40	1.015.008,15	-802,79	-96.334,85	-8,67%	-8,67%
Indifferentiated arable land	230,48	27.657,40	230,46	27.655,15	-0,02	-2,25	-0,01%	-0,01%
Vegetable crops	1,34	161,20	1,34	161,27	0,00	0,07	0,05%	0,05%
Vegetable crops (irrigated)	551,27	66.152,06	468,50	56.220,55	-82,76	-9.931,51	-15,01%	-15,01%
Permanentwoodagriculture	89,75	10.770,08	89,78	10.773,24	0,03	3,16	0,03%	0,03%
Pastures	3,98	477,20	3,98	477,28	0,00	0,08	0,02%	0,02%
Agriculture/naturalland	743,53	89.223,18	702,12	84.254,89	-41,40	-4.968,29	-5,57%	-5,57%
Broad-leavedforest	1.524,66	182.959,00	1.398,34	167.800,22	-126,32	-15.158,79	-8,29%	-8,29%
Water courses (natural)	3,85	462,27	3,85	462,45	0,00	0,18	0,04%	0,04%
Water courses(artificial)	0,03	3,89	0,03	3,89	0,00	0,00	0,02%	0,02%
average/tot	30.380	3.645.636	29.363	3.523.586	-1.017,09	-122.050,2	-3,35%	-3,35%

Table 3 shows the ES valuation, for Carbon Sequestration function, of both biophysics/economic values. Such evaluation is a typical output of a context based analysis, derived by a distribution of values for all land use classes detected inside the case study. The assessment is defined by a LUC analysis, associated to an ES mapping of biophysical values applied to a t0 (which is the present land use/cover situation) and a t1 (which is the planned scenario of land use transformation). This simple comparative analysis between existent and planned land uses shows that each single category is affected by variation in the provision of the specific ES of Carbon Sequestration.

The evaluation shows that planned land uses decrease the total carbon stored on soil from 30.380 tons to 29.363 tons. Such carbon loss is equal to an economic decrease of more than 122.050 euro, with a rate of decreased value between existent and planned scenario of 3,35%. Moreover, the single variation, demonstrate that maximum decrease in values is concentrated on Uncoltivated urban areas (-2.608 tons stored), and that maximum growth due by the new Urban Parks (gain of 1.903 tons stored). Similar trends are registered for the decrease in value of Agricultural areas (- 802 tons) and the increase of Green generic areas (674 tons) or the Continuous urban fabric (non dense), which increase the value (of 396 tons).

These data are a good indicator of the plan strategy, because Bruino acts with a policy of land use “infilling”, converting the residual open spaces closed to the built up system into new urban low dense zones. Such transformation, is typically accompanied by the provision of new green urban zones, which guarantee a high degree of quality to urbanization.

In that case, even if the overall process of artificialization due by the panned scenario is equal to a growth rate of 5,56%, the decrease of the Carbon Sequestration service is “smaller” (-3,35%), because the planned LUC guarantee a low decrease or efficiency for the specific ES considered.

This is a typical trade-off between alternative function evaluated using one ES as a proxy, that demonstrates which is the lost benefit derived by a land use scenario. The assessment of such evaluations support a strategy of resilience during planning phase, because it allows to achieve better balances between sustainable land use functions. Therefore when efficiency is used as a proxy for better land use allocation, than resilience is provided.

4 How to balance trade-off among different values

As written before, one of the major task for accompanying planning decision is the indication of a SQI here intended as a multisystemic approach on ES.

Indeed, it is necessary to overcame the main limitation of a single ES analysis that quantifies only a single process in the total amount of processes regarding the land use transformation (in particular, it allows to quantify the single effect of a LUC over specific ES observed).

When a process of urbanization occurs, multiple processes are simultaneously happening. Considering only the plain variation of land covers by LUC it is normally possible guarantee a statistical information on land take trends. But related processes (e.g. the “sealing process” and its effect on hydrological cycle, rather than the alteration in the capacity of soils to support primary production) affects covers with different degree and effects on ecosystem and landscape[8].

Normally, when an agricultural field is urbanized, the productive capacity downgrades, and may be completely neglected in the future. For many reasons productive capacity is also the major indicator of soil quality considering the fact that i) land take affects mainly agricultural fields, ii) agricultural land has a high suitability for productivity capacity because of the high fertility of such soils, and iii) high fertility is associated to good geological characteristics and thus is generally considered a good proxy of “quality”.

Nevertheless, the reduction of the trade-off balance among different ES to a binary alternative between urban and agricultural values is flattening the possibility to really reach a complex system of knowledge on soil efficiency performance able to support planning activities. This is why SAM4CP considers all the main ES to define, with an indicator based approach, a set of rules or guidelines for best practices of sustainable land use aimed to increased soil resilience.

Within this target, a composite SQI has been tested to find a balance of trade-off among different ES, with a research focused on the definition of “patterns” where soil efficiency of ES is represented and interpreted as a qualitative support for the decision making process.

SQI was generated with a “weighted overlay” function associated to single’s output ES model. A weighted sum of cell for specific ES was launched with ArcMap version 10.2. InVEST model’s output generates a raster distribution of both positive and negative values. Indeed, to transform negative to positive, the weighted overlay uses the “conversion” for crop production, multiplying the value for – 1, and the water purification for –1 too.

The output was converted using a “raster to polygon” function for the cell field “value”; than normalization with a range from 0 to 1 has been applied using Excel (normalization function) with the .dbf file. Geographic distribution of values has been reached joining the table to a new shapefile called “multisystemic values”.

4.1 A Soil Quality Indicator as a proxy of efficiency

As introduced, SQI was prepared to outline a “pattern” characterization of the specific information provided by efficiency of each land use class.

In order to visualize the different “dimensions” of land uses, spider charts were designed: the vertices of the charts represent the selected ES variables for a multidimensional representation of efficiency of land uses. The representation by spider charts, shown by Figure 1, tends to hold together disjoint variables. We aimed to give an adequate representation of the “multidimensional” aspect driven by land use phenomena.

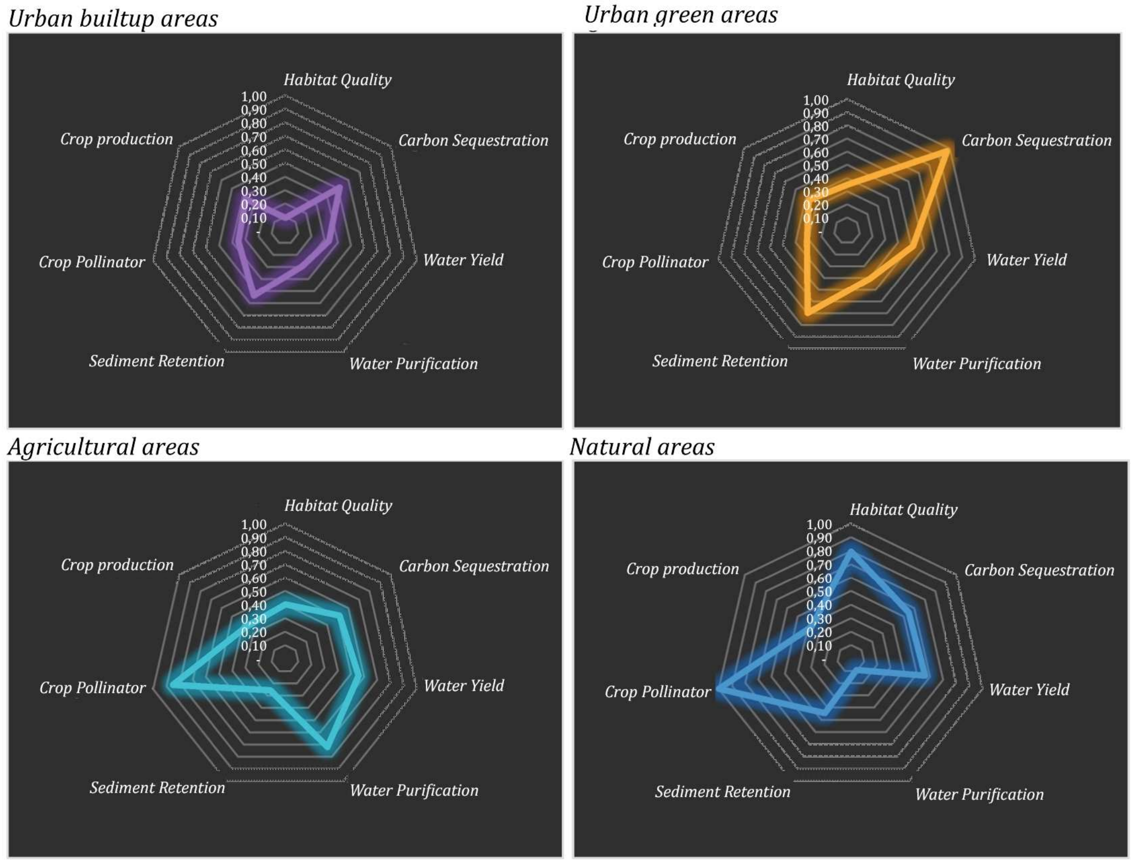

Figure 1 Land use efficiency patterns

As it is possible to see, significant different patterns are represented to the Figure.

Firstly, it has to be stated that the two values below the chart (Sediment retention and Water purification) represent the contribution of soil to produce erosion and water pollution, thus good performance are indicated by low values and viceversa. For all other functions low values correspond to low performance and viceversa.

Urban builded areas: the pattern shown an average ES performance clustered to che centre of the graph, whithout any specific cusp. It means that generally urban soil in Bruino performed low quality of ES, with a tendency to register higher performance for Carbon Sequestration, because the build-up system is “porous”, and such porosity does not affect the Carbon Sequestration function.

Urban Green areas: the pattern reveals that urban green areas play foundamental role for ES maintenance. The performance is generally high, only productive capacity is, obviously, lower than other ES. Maybe for geological reasons, those areas generate also erosion, but provides the higher values for carbon sequestration, and optimal values for water cycle regulation.

Agricultural areas: the pattern shows a general good performance of such land use for all ES, in particular the pollination service is high, due to the fact that some agricultural fields are optimal to nesting sites allocation. But also water cycle regulation and carbon sequestration have good values. Nevertheless, water pollution is critical, because the use of fertilization have great impact with the nutrient retention capacity.

Natural Areas: obviously this pattern shows the great feedback with Habitat Quality. It means that the overall ecological quality of this land use in Bruino provides good quality for all animal and vegetal species. But better results are achieved by impollination function. Also carbon sequestration and water cicle regulation is optimal, even if productive values are low.

And what about efficiency? Seems that the four observed land use categories generally demonstrate that none of considered ES is completely neglected by specific land use. In terms of comparative analysis, efficiency increases as long as the pattern covers a higher distribution on good qualities. By the way, it is pretty simple to recognize that the cluster of Urban builded areas is less efficient of the ones of Urban green areas. More the pattern shows a general good quality, and more the potential tradeoff between different functions during a planning phase have to “ponderate” how to achieve a good balance for newer scenarios.

Such kind of knowledge contributes to evaluate different options of mitigative/compensative actions for a sustainable land use transformation, also taking into account climate change mitigation policies aimed at increase the performances of soil to act as a carbon pool and as a filter for the general air quality.

5 Conclusions

The creation of a system of knowledge on ecological quality of soils, using ES assessment as a proxy for SQI, gives to planners and administrations the possibility to select sustainable targets for resilient policies and actions. The more ES knowledge and mapping is deep, the more such knowledge can really support land use planning activity and its operability with processes and projects of territorial governament.

By the way the assessment of soil quality is helpful for considering a single’s soil function, and thus select specific target of resilence, rather thanconsidering a cumulative evaluation based on a sum of different SQI, pursuing a general target of sustainability in planning.

Obviously, the construction of a composite indicator on SQI is dependent from the availability of a huge amount of datasets, and also their precision; nevertheless, the ecological assessment of soil is finalized to integrates planning procedures, in particular a target of SAM4CP is to bring into the phase of Co-planning Conference the evaluation of soils and its implication for the Strategic Environmental Assessment for planning policies definition.

The consensus building approach based on a deep knowledge of ES trends and dynamics is shading lights on some planning issues related to sustainability of land uses: only a qualitative knowledge, rather than quantitative, supports practices of mitigations or compensations for urbanization.

Bringing such approach into planning practicies means to improve the performances of land use resilient strategies, here intended as the possibility to achieve a long term land use efficiency by planning practices. If resilience is the capability of a city to adapt to any external intervention, both man-made or caused by climate change, in order to restore its own balance, than a indicator-based approach of the tradeoff among different function helps planners to reduce discretionary variables during decision-making phase.

Even if the approach is far away to be considered "easy", the presented methodology should support a real innovation for achieve a real sustainable land use management for local communities. More and more the issues of efficiency will bring into territorial governance new challenges: soil is a scarce resource, the competition for alternative use will certainly increase, because the global trend of population is growing. Within this perspective strategies of adaptations are required also for steering territorial policies. This is why, up to now, new methodologies of land use analyses for planning practices are welcome, even if not fully tested.

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